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Guide to the dalles of the

St Croix

A Guide to the Dalles of the St. Croix for Excursionists and Students.

By Charles Peter Berkey, Ph. D. Instructor in Mineralogy in the University of Minnesota.

MINNEAPOLIS.
THE UNIVERSITY BOOK STORE.
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GENERAL VIEW OF THE ST. CROIX ABOVE THE DALLES.

GUIDE TO THE DALLES OF THE ST. CROIX.

LOCATION AND GEOGRAPHY.

One of the most interesting and picturesque localities within reach of the chief centers of population of Minnesota is the Dalles of the St. Croix. At a point about fifty miles northeast of Minneapolis and St. Paul the St. Croix river has cut its way through hard igneous rocks which form high vertical walls, canyon-like in their appearance, and which are attended by many rather unusual geological and physiographic features. The most extensive outcrop of this character is in the immediate vicinity of Taylor's Falls, Minn. Two miles farther down the river, near the small village of Franconia, the Lower Dalles may be seen.

The St. Croix river forms the boundary between Minnesota and Wisconsin at this point. Communication between the two states is by means of a toll bridge—probably the only one of its kind in either state. It forms the connection between the two companion villages, Taylor's Falls and St. Croix Falls, one on either side of the river just above the Upper Dalles.

Taylor's Falls is at the head of navigation on the St. Croix. The old boat landing, one of the busiest spots in the early days, has been almost abandoned for many years. Before railroads were constructed in the adjoining territory, when river boats on the St. Croix and Mississippi carried most of the trade of a growing commonwealth, this place was a busy commercial center. Mendota, Stillwater, Hastings, St. Paul and Minneapolis were other growing towns of scarcely greater promise. Overland shipping by rail has made other points better centers of distribution and the natural advantages of other portions of the state have tended to move population and trade farther westward.

This is the southern limit of the white pine as well as the southern limit of the Keweenawan rocks. The first saw mill in the state was located only a few miles below the Dalles, and to this day the St. Croix river has not ceased to be one of the chief driveways for pine.

REFERENCE BOOKS AND ARTICLES.

The following references contain descriptions of the Dalles of the St. Croix and vicinity. For a thorough understanding of the geology

THE GREAT LOG JAM.—SIXTY MILLION FEET OF PINE TIED UP AT THE DALLES.

of the district, a careful study of the references given will be found most helpful.

Chamberlin-Strong: 1880—Geology of Wisconsin, Vol. III, Pt. VI, pp. 365 to 428.

Winchell-Upham: 1888—Minn. Geol. Surv., Final Rep., Vol. II, pp. 399 to 425.

Upham: 1896—Rep. Com. Interstate Park, Lecture, pp. 45 to 60.

Berkey: 1898—Geology of the St. Croix Dalles (a thesis), 88 pages.

PART I.

GEOLOGIC HISTORY.

At the time the oldest rocks of this district were formed the greater part of Minnesota and Wisconsin was occupied by the sea. It is claimed by geologists that northeastern Minnesota and northern Wisconsin and Michigan then formed a part of the continental area. Toward the west and south the expanse of open sea seems to have been very great. The rocks formed during this period are known as the Keweenawan or copper-bearing rocks. Good outcrops of them are to be seen in the vicinity of the Dalles. They are basalts or old lavas chiefly.

This was a period of the most extraordinary volcanic activity. Lavas were poured out in immense sheets from great fissures in the crust of the earth and spread out over thousands of square miles in the Lake Superior region. One flow after another was poured out—sometimes separated by a short period of erosion and its accompanying sediments of sandstones and conglomerates, and sometimes accompanied by such violent explosive outbursts as to cover the entire surface with ashes and cinders to a considerable distance. Such materials finally accumulated in a fairly definite and distinct series of rocks which have a total thickness of several thousand feet. The Dalles is near the southwestern limit of this formation.

After volcanic action became more subdued, a long period of time elapsed during which the bare rock surface was exposed to the destructive forces of erosion. Ravines and gorges were cut into these solidified lavas with such persistence and success that hundreds and perhaps in places even thousands of feet in thickness were worn away from the surface of these rocks. Ridges and valleys may still be seen in the vicinity of the Dalles showing a difference in elevation of more than 500 feet.

The time required for such erosion is the measure of the interval between the close of the Keweenawan and the beginning of deposition of the next succeeding or Cambrian rocks.

At the close of this erosion period the continent gradually sank beneath the sea. The higher ridges stood long as rocky islands and headlands in the advancing ocean. Conglomerates belonging to the Cambrian age were formed along the rock-bound, wave-battered shores, as may in places still be seen in the vicinity of the Dalles. Farther from the shore sands accumulated with mud and the shell remains of many low forms of animal life, which all together were formed into great beds of sandstone and shales. They may be seen in the river bluffs both above and below the Dalles.

These sedimentary rocks are of immense thickness and great geographic extent. They covered probably all of the area of the Keweenawan rocks which preceded them and stretched several hundred miles off the southern margin of the primitive continent. How thick the accumulation finally became in the Dalles is left largely to conjecture. It certainly covered all the high ridges of igneous rocks which now crop out through them, and there may have been several hundred feet more which have since been worn away. The comparatively soft sandstones and shales were rapidly cut into and destroyed. That a large amount of this formation was in the long ages succeeding carried away by the streams is well substantiated by a study of surrounding territory, and that certain of the original calcareous and shaly formations, by the dissolving power of percolating water, have been greatly changed from their original petrographic character is equally certain. In this manner great quantities of calcium carbonate have been carried away by the waters in solution, while the more difficultly soluble constitutents have been left behind, forming numerous varieties of dolomites and shales.

In all probability the continent again sank beneath the sea. But if it did, there are no corresponding formations now left to record the event for us. Such deposits, if they did exist, have been wholly removed by later erosion.

Then a great geologic revolution—the ice age—came. Immense streams of ice in great sheets scoured their way through valleys, over ridges and across all merely local inequalities, carrying sand, gravel and boulders many miles from their parent ledges and scattering them broadcast—a wonderful mixture—upon the land. Such debris covers the greater portion of northern United States. In general the ice invasion came from the north. Tongues from the central masses were often deflected from their southerly course by uniform local conditions, so

we have glacial debris carried eastward and westward as well as southward from original localities.

These conditions lasted a long time—possibly a hundred thousand years. And at its close—not very long ago, perhaps twenty thousand years—present conditions were inaugurated. The climate became temperate again. Erosion once more set in. Streams sought new channels. Soils accumulated upon the deserted surface of the drift, and the physiography of the northwest began to be what it now is or finally will become.

POSITION IN THE GEOLOGIC SCALE.

The following tabulated column will give a better idea of the vertical range of the rocks occurring at the Dalles than any mere description is likely to afford:

Cenozoic Era (2,900,000 years)—
- Quaternary period—Represented by recent and glacial deposits, in the Dalles area, 200 feet.
- Tertiary ..... absent

Mesozoic Era (7,240,000 years)—
- Cretaceous ..... absent
- Jura-Trias ..... absent

Paleozoic Era (17,500,000 years)—
- Carboniferous ..... absent
- Devonian ..... absent
- Silurian ..... absent
- Ordovician ..... absent
- Cambrian—Represented by sandstones, shales, dolomites and conglomerates, 300 feet.

Agnotozoic Era (17,500,000 years)—
- Keweenawan—Represented by numerous lava flows and associated breccias and volcanic ash. Appearing at the Dalles as a massive igneous rock—diabase, 4,000 feet.
- Animike .....absent or not exposed
- Keewatin ..... absent or not exposed

Archean Era (10,000,000 years)—
- Mareniscan ..... absent or not exposed
- Laurentian ..... absent or not exposed

The approximate comparative duration of successive eras are estimated in years. It will be seen that only a small portion of the column is represented by the rocks of the Dalles area.

IGNEOUS ROCKS. ROADS AND STREETS. FARM HOUSES

MAP OF THE DALLES AND VICINITY.

(Sixty square miles.)

PART II.

DETAILED EXPLANATION OF LOCAL GEOLOGY.

A—Surface Features and Recent Geology.

The surface features and contour of the district are wholly of glacial origin, modified only by the erosion accomplished by the present rivers and smaller streams. Bordering the river on the west is a large and comparatively level plain of till. It is typically developed in the vicinity of Franconia station on the St. Paul & Duluth railway as one enters the district. Little change can have been accomplished by post-glacial agencies on this particular tract beyond the drainage of a few shallow lakes and sloughs left by the retreat of the glaciers. Drainage is sluggish and largely subterranean, so that waters which sink into the soil at last find their way through the underlying beds of sandstone to lower levels and issue as springs along the river bluffs and other places. It is a good farming district.

The adjacent territory in Wisconsin lying just east of the river is comparatively rough. It is also of glacial accumulation, but of a different type. The St. Croix moraine lies almost parallel to the river, and the usual characteristic kettle-hole contour is presented in perfection over a considerable area. Two or three level tracts of rather limited extent accompanying this moraine belt are intimately connected in origin with local conditions prevailing at the time of the retreat of the ice sheet. Most conspicuous among these is the terrace-like tract bordering the river just east of St. Croix Falls, and also the glacial flood plain in which Dresser Junction is situated. The former lies at an elevation of 1,020 feet, while the latter is nearly 100 feet lower.

But the feature of greatest prominence is the river and its accompanying phenomena of erosion. The St. Croix river has cut down into the glacial drift and underlying rocks from two to three hundred feet below the average elevation of its territory, and more than 400 feet below some of the igneous ridges which outcrop in the vicinity. As one enters the gorge by the St. P. & D. Ry., immediately upon leaving Franconia station, the whole character of the geologic environment suddenly changes. Whereas the train has passed for an hour through a level and monotonous drift district, it now plunges in less time than it can be told into a new river valley where every contour has been chiseled by erosion. Not a trace of the original drift

surface can be seen. Upon entering the valley this proves a most delightful scenic innovation, and its study a most interesting and instructive field experience.

B—River Erosion.

The prominent physiographic features presented by the action of the river are terraces, abandoned channels, river lakes, river dams and a remarkable accompaniment of the erosion of the igneous rocks usually known as pot-holes.

(a) Terraces.—There are five terraces to be seen in the immediate vicinity. At about 905 feet above sea level the first or highest terrace forms a very prominent bench which is known in Taylor's Falls as the "picnic ground." It also occurs in more limited extent on the Wisconsin side of the river near the railway station. It seems to be closely associated with the retreat of the ice from the vicinity. Succeeding

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ones, however, are simple river terraces, and are quite as easily traced farther down in the gorge.

The second terrace follows the 810 foot contour line and is most easily studied on the east side of the river. It forms a comparatively narrow bench along which the main business street of St. Croix Falls is built, and may be traced throughout the village.

At 780 feet on the east side of the river a third terrace is developed to a considerable distance above St. Croix Falls.

At 750 feet on either side of the river the fourth terrace forms the conspicuous and extensive level tracts bordering the present river channel, 50 or 60 feet above the water level. The business portion of Taylor's Falls is built on this terrace, and River street, as far as the upper falls, is a part of the same bench. Also on the east side of the river it is the same terrace on which the mill is built, and on which the abundant spring water is collected to furnish its power.

A fifth terrace at 725 feet has a very limited development near the toll bridge.

(b) Abandoned Channels.—The St. Croix river has been turned from its present course several times in its late history. Two abandoned channels are within reach, one of them of considerable importance and interest. A small side channel may be seen in the north portion of Taylor's Falls near the freight depot. A large and well marked one extends southward from the elbow in the Dalles. It is about two miles long, reaching the river again less than a mile above and opposite Franconia. It was abandoned at the 800 feet contour, 100 feet higher than the present river level, upon reaching a bed rock of diabase, which made deeper erosion along its course extremely difficult and slow. The present channel lies considerably to the west, and passes almost wholly through much softer sedimentary rocks.

At a much later stage a part of this channel immediately next to the Dalles was still used. It is now marked by the river-lake Thaxter, which lies in the old channel at the level of the present river. At that time in the history of the river there must have been a considerable fall at this place, where the water pouring over the igneous rocks plunged down into the easily eroded sandstones adjacent. A fall of 50 feet, and perhaps 100 feet, seems to be a reasonable estimate upon the evidences of filling of the abandoned lake Thaxter channel and accompanying phenomena of erosion. The precipice forming the brink of the abandoned falls may be seen a little off the road leading to Thaxter lake, just below the elbow in the Dalles. The entrance to this channel is about 50 feet above the present river.

(c) Pot-holes.—At the Dalles, and also a mile above the Dalles, there are a large number of deep holes called pot-holes worn into the hard igneous rocks. They are forming in the present river bed, and are also found even more abundantly on the terrace-like benches to an elevation of more than 50 feet above the river level. They seem to have been an accompaniment of the destruction of these persistent rock barriers from the beginning of river erosion.

In their best and most typical development probably few localities in America are more favored than this. And in few places also is the question of their origin more clear or their history more intimately connected with other geological questions of considerable local importance. It seems clear from a study of the locality that all of these holes have been formed by swiftly running water, whose swirling eddies, produced by the unevenness of the rock floor, have carried loose sand and gravel round and round so persistently that great holes have been literally drilled into the hard crystalline rocks which formed the river bed. Each hole was then filled with a rotating column of water at whose top the onward flow of the river furnished power enough to keep it in rotation, and at whose bottom pebbles and sand and boulders rolled round and round year after year and century after century—boring the hole deeper and grinding the pebbles smaller—until the river deserted its task or accomplished the object of its toil. Untold thousands of pebbles, imprisoned in these great mills of nature, ground themselves to atoms only to be replaced by as many others swept down by the floods as were those which preceded them—all used as slaves by the river as a great live monster to grind away this defiant obstacle to his progress.

And when were all these made? Only yesterday. Yesterday morning, geologists say, the great glaciers of the ice age were beginning to melt away. Their floods have left only here and there so magnificent a record of their existence and power.

At the close of the ice age the St. Croix river carried an immense volume of water contributed by the melting ice of the retreating glaciers. And it was also at that time the outlet of Lake Superior, when that lake was 500 feet deeper than it is now, and when it drained into the Gulf of Mexico instead of into the Atlantic Ocean.

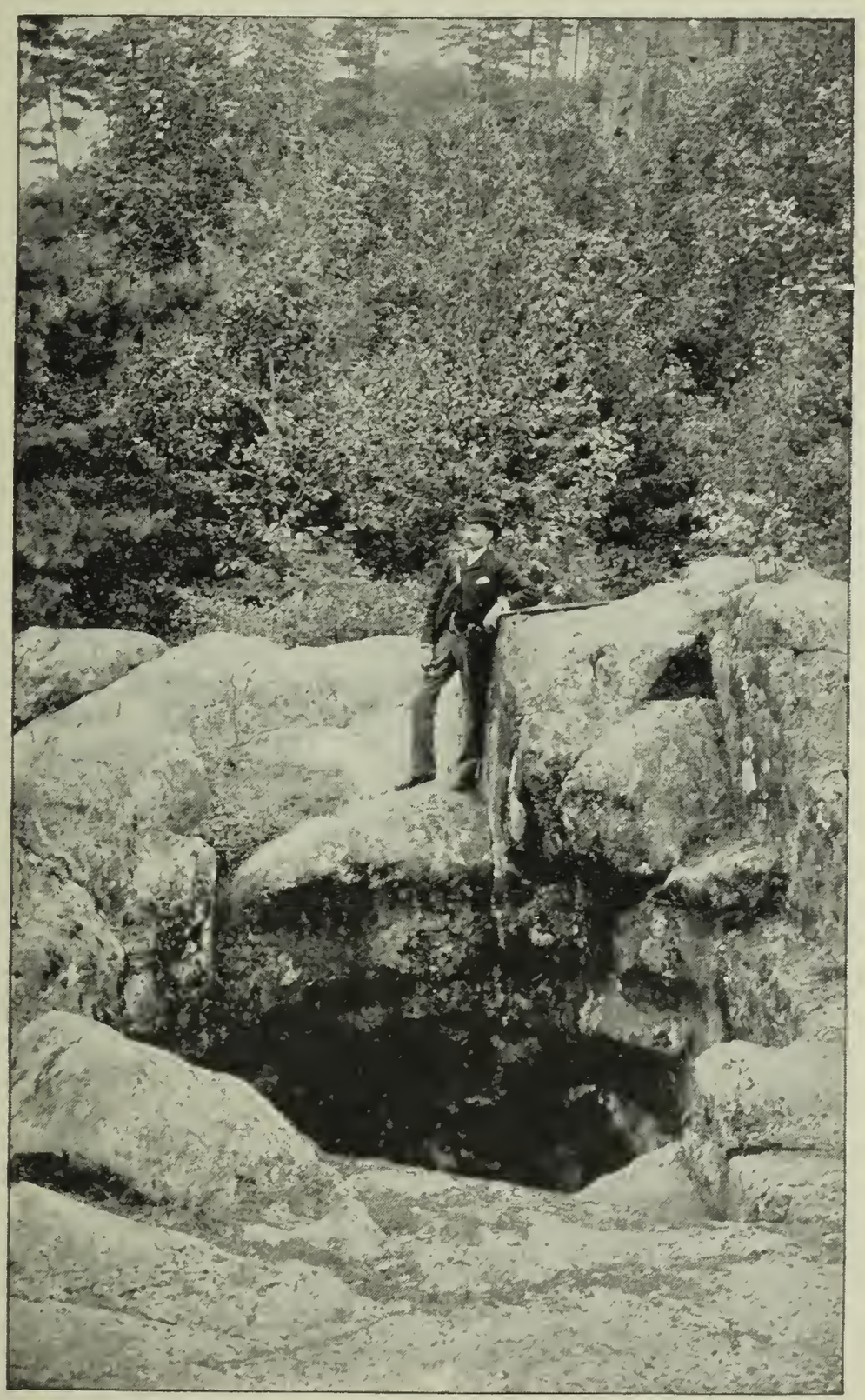
C—Glacial Geology.

Glacial accumulations in this vicinity belong only to the later part of the ice age. Nothing is necessarily referred to an earlier stage than the Wisconsin, although there may be deposits older in the adjacent territory. The glacial debris as till and modified drift is abun-

dant here, and in places is of considerable thickness. It is distributed both in level tracts and in moraines. The range of hills to the east of St. Croix Falls constitutes a typical morainic belt.

There are three easily separable subdivisions in the mantle of drift which covers most of the district. The first or earliest differs from the second both in character and time of accumulation, while the third differs from the first only in time.

The first or underlying sheet of drift is a red till, the so-called



ONE OF THE LARGEST POT-HOLES.

eastern drift of the Minnesota geologists. It is in many places 40 to 50 feet thick, and is sometimes faintly stratified as if deposited in quiet water.

The second or middle drift is gray in color, calcareous in distinguishing character, and in its chief exposures is a typical western till. It is the gray or western drift of the Minnesota geologists.

The third or latest drift is found in isolated areas on the west side of the river, and forms the whole of the moraine on the east side of the river, beyond which no western material has yet been found.

All of this material was accumulated where it now lies during the ice age, and most of it, at least, at its very close. Pebbles and boulders may be gathered at many places which must have been carried one or two hundred miles from their parent ledges. As nearly as can be learned from the evidences to be seen, the situation must have been essentially as follows: A glacier moving southward or southeastward from the lake region pushed across the district into Minnesota territory to an unknown distance, spreading out and leaving behind upon its retreat a great thickness of debris brought from the iron-bearing and neighboring districts, and which is because of its content usually of a red color. Later a similar arm of the great western ice sheet from the Red river valley pushed in toward the St. Croix, spreading the western drift, which carries a considerable amount of limestone debris from western localities. This later invasion barely crossed the St. Croix river. By the time it had reached the Dalles, the eastern ice advanced again to dispute its progress. As a result the two stood probably for a long time directly opposed to each other, at times one encroaching upon the territory of its antagonist, but at last both retiring from the scene, while in the gap between them the post-glacial St. Croix was settled into its present course.

The river gorge is post-glacial. The old or pre-glacial channel is yet unknown. It may have passed to the west farther, perhaps through the Chisago lakes, but upon the retreat of the western ice invasion the old channel was so badly filled with drift that the new one at the Dalles became permanent.

D—Sedimentary Rocks.

Sandstones, shales and conglomerates of upper Cambrian age include all of the typically sedimentary rocks occurring at the Dalles. But in adjacent territory southward from this locality later formations occur as high in the scale as the Devonian age. Those formations belonging to the Cambrian age have been divided on petrographic grounds into two series. Formations belonging to the lowest or

arliest series are chiefly sandstones and shales; those belonging to he next later series are chiefly dolomites and associated dolomitic hales or sandstone. The tabulated double series is formulated below, eginning with the latest formations belonging to them.

Upper Cambrian Rocks.	Magnesian Series.	Shakopee dolomite—65 ft.	absent
		New Richmond Sandstone—20 ft.	absent
		Oneota dolomite—75 to 175 ft.	Osceala
		Jordan sandstone—75 to 200 ft.	Osceola
		St. Lawrence dolomites and shales 30–2.0 ft.	Osceola
	Basal Sandstone Series.	Franconia sandstone—100 ft.	The Dalles
		Dresbach shales—150 ft.	The Dalles
		Hinckley sandstone—0 to 1000 ft.	not exposed.

Two of these formations may be examined at this locality. The Franconia sandstone is a white, friable quartz sandstone which forms he bluffs along the St. Paul & Duluth railway a mile below Taylor's Falls. Almost its total thickness is exposed here. It contains few ossils, and is of little value for economic purposes.

The Dresbach formation is also well developed here. It includes he lower shaly beds of the gorges along the railroad where the Franconia sandstone was studied, and it also includes the calcareous beds o be seen above the Dalles on either side of the river at intervals for several miles. Probably the best exposures are within a mile above the Dalles. These shales, where there is a considerable content of calcium carbonate carry large numbers of fossils. Fine specimens of *Lingulepis pinniformis* Owen (*Lingulepis acuminata* Conrad) may be easily obtained. An interesting shale which is heavily charged with secondary concretionary pyrite occurs near the carding mill on the west side of the river, half a mile above the toll bridge.

Perhaps the most interesting and unusual accumulations, however, are the conglomerates which lie in contact with the igneous rocks in several horizons. They are made up wholly of large and small diabase boulders and pebbles from the adjacent cliffs or shores and the interstices between them are filled with sand and other finer materials. The cementing matter for these fragmentals is both calcareous and ferruginous—in places calcium and magnesium carbonates occurring in great excess, while in others ferric oxide constitutes the chief cementing substance.

Conglomerates of comparatively little thickness are no doubt of considerable extent along the zone of contact between the sedimentary and the igneous rocks. But because of such a position there are necessarily few places uncovered by erosion so as to exhibit this conglomerate in its best development. The most extensive outcrop, and the one most easily accessible to excursionists, is also the most profit-

able to examine. It may be seen at the crossing of Mill street wit the St. P. & D. R. R. as a ragged bluff, showing a thickness of con glomerate of about 20 feet. Following it along to the brow of th hill excellent specimens may be obtained where the road passes directl over this splendid outcrop of conglomerate. This place is one bloc southwest from the public school building. Another outcrop may b seen in the river gorge on the Wisconsin side nearly a mile above th Dalles. Still another is exposed in the gorge on the Minnesota side two miles south of Franconia village. It rises from the water leve as a vertical bluff 50 feet high. It is one of the most conspicuou landmarks seen from the river.

All of the boulders of these conglomerates show much wate wear, such as might be produced by wave action along the shore Considerable variety of mineral content is sometimes encountered Crystallized calcite, dolomite and copper compounds in geodes and fissures are most common. In these conglomerates are also found sometimes fossils of extremely rare types.

E—Igneous Rocks.

The Keweenawan eruptives are the most ancient rocks outcropping in the vicinity. They form the Dalles and are abundantly exposed in the adjacent territory. The most satisfactory place for a study of these rocks is in the village of Taylor's Falls itself, where they form the surface over a large area. Important data bearing upon the interesting question of origin and subsequent history have been obtained here. On account of the rare opportunity offered for the study of a number of structural problems under so favorable conditions, a few questions will be discussed briefly and the best places for their study pointed out.

1.—Origin.

Throughout the whole extent of the Keweenawan rocks as seen at the Dalles, there are but two kinds of rocks as to method of origin and those two probably have the same ultimate source. The two kinds are (*a*) the compact hard, dark green, crystalline rock of diabase type which forms the body of each successive flow, and which constitutes almost the whole thickness of this formation; and (*b*) a fine or coarse-grained ash-like or brecciated interbedded fragmental rock which occurs in comparatively thin layers or beds between successive lava flows. Although these two are so radically different in method of formation, they are not always easily distinguished. A thorough study, however, of type specimens of each and a comprehensive understanding of the geologic structure of the formation will in a little time enable one to recognize them in the field.

As to the ultimate source of these kinds of rock, they are both alike of volcanic origin, one a sheet of molten lava poured out either from great fissures or immense craters, and the other as fine ash and bombs originating in violent explosions from active volcanoes. Associated with this last is the broken and shattered material usually formed upon the surface of an advancing stream of solidifying lava. This in places forms a remarkably fine example of a volcanic breccia.

During the time of accumulation of this formation the area was certainly a land surface. All associated evidences of water action are limited to surface wash such as might arise from heavy rain storms which usually accompany explosive volcanic activity. Even the stratified appearance of the ash accumulations are indicative of such origin, rather than that they were deposited in or beneath the sea. The centers of the greatest activity were probably to the northeast, where

BOATING IN THE DALLES.

this same formation has a very extensive development on both sides of Lake Superior.

2.—Separate Flows—or successive periods of activity.

A lava flow, i. e., a lava stream or sheet forming a unit in the series and belonging to a single period of eruption, has certain constant peculiarities of structure which it is essential to understand at the outset. The most general of these are a compact, more or less completely crystallized lower and middle portion, and a vesicular more or less glassy or felsitic upper portion. Two independent flows are separated by a persistent lateral plane, which also marks the accumulation of ash, bombs and breccias. When a formation composed of such materials belongs to a remote age, as in this case to the Keweenawan, the immense time which has since elapsed has given ample opportunity for much alteration or metamorphism of the rocks. Their original condition is indicated only by secondary products and structures which require intelligent geological interpretation. In the present condition of these rocks, as they appear at the Dalles, the following characters are repeated with comparative uniformity in each successive flow.

At the base of each flow the rock is a compact, very dark green diabase. It is thoroughly crystalline, commonly lustre-mottled in the lower and middle portions, and made up of the primary minerals, augite, plagioclase and magnetite, with or without the secondary minerals, quartz, epidote and chlorite. In the middle of the flow there is little change from this, although occasionally there is a considerable development of pseudo-amygdaloid. Toward the top of each flow there is commonly a vesicular or amygdaloidal condition of the diabase. The color is yellowish green. Epidote is more abundant as a secondary mineral. Quartz, chlorite, epidote, calcite, feldspar and actinolite are secondary in amygdules and pseudo-amygdules, and also among the crystal grains as alteration products. Vertical jointing is usually most pronounced in the middle and lower portions, while lateral parting is most persistent at the surface of each flow. The discovery of ash at several points, which in each case agrees with the subdivisions as defined above, confirms the conclusion that the number of times this group of characters is repeated in the series is an accurate measure of the total number of flows poured out upon the area.

The number of these flows exhibited in this single outcrop at the Dalles is about ten. Seven of them are readily followed on the west side of the river as one proceeds from the elbow in the Dalles over

Fig. 1.—Profile of the area along a line drawn through Colby and Poplar lakes, showing Glacial Drift, Cambrian Sedimentaries and Keweenawan Diabases.

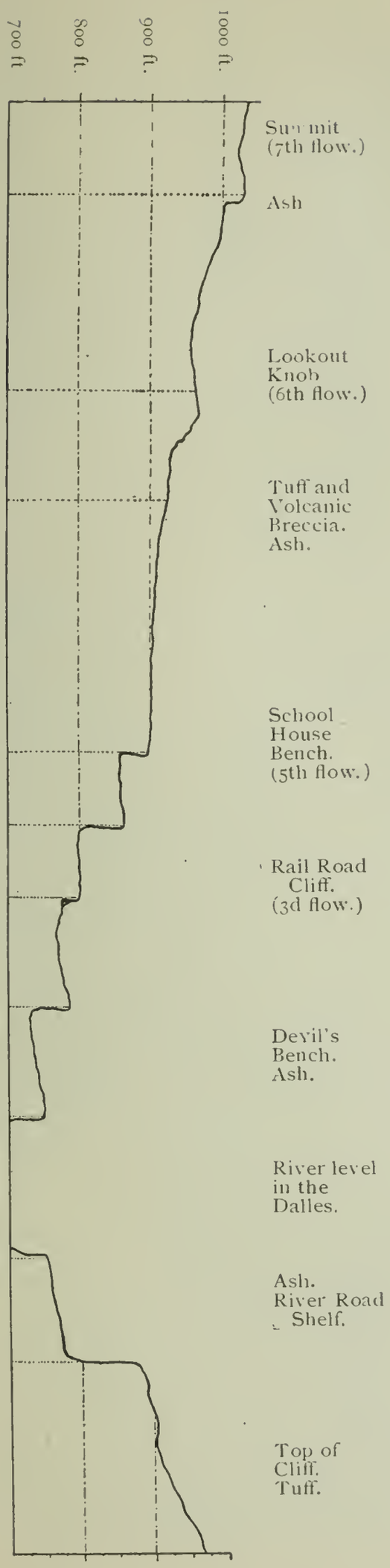


Fig. 2.—Profile of Igneous Rocks at the Upper Dalles, Taylor's Falls, Showing the Separate Flows.

the successive steps and benches to the public school building and beyond. The average thickness of each is from 30 to 50 feet. All dip at a low angle toward the southwest. In general, erosion has produced a step-like contour which proves to have a definite relation to the fundamental geologic structure.

The key to this separation is to be seen along the street leading to the steamboat landing. The surface of one flow forms the bench on which the street is located, and at several places a narrow shelf rises a few feet above the street level, while upon it the next succeeding flow rises as a perpendicular cliff 50 feet high. Differences between textures and other characters exhibited by the top and base of two flows in contact should be seen at this place. A repetition of this association under less favorable conditions for satisfactory observations may be seen at other horizons, both above and below.

3.—Volcanic Tuff.

This is a name applied to the fragmental material accumulated between and associated with the lava flows. The most extensive development of this rock shows a thickness of about 20 feet in one bed. One block west of the public school building is the best place to study this bed, where it extends along the strike of the formation entirely across the ridge.

Tuff may be recognized at several other places by the following characters, some of which are present in every occurrence. It is composed of both very fine and very coarse fragments, which are so firmly compacted through metamorphic processes as to present a hardness and general appearance similar to the adjacent diabase. But upon close inspection the clastic character is observable at many places in the field, and under the microscope many specimens show a similar origin even when the unaided eye can detect no evidence sufficient to separate them from the altered diabase. The coarser fragments of the tuff are angular pieces of igneous rock, which frequently exhibit a vesicular or an amygdaloidal structure. They are the shattered crust of the flows, such as accumulate upon the surface of solidifying lavas while in motion. Finer grains in the tuff are of several different types, and likewise of different origin. Many individuals show considerable wear into rounded grains of a size not very different from those of a fine sandstone, while others, and notably the smallest or finest particles, are angular and show little wear.

Much of this material is typical volcanic ash. It accompanies explosive activity, and is in fact the only evidence of such violent volcanic disturbance found in the district. Grains are found which,

DEVIL'S CHAIR.—A PRODUCT OF JOINTING.

when examined with the microscope, exhibit all stages from a glass through its devitrification aspects to a clearly crystalline condition similar to the diabase of the brecciated portion. Furthermore, in the alteration or metamorphism which has taken place a large proportion of the fragments are now completely changed from a glass-like obsiddian to grains of the secondary minerals, quartz, epidote and chlorite, which preserve perfectly the original outline.

In several places the ash exhibits characteristic banding usually belonging to the water assorted materials of sedimentary rocks. This was probably done by the rain storms which accompany volcanic disturbances, and the resulting streams are no doubt responsible for such wear of fragments and grains as was accomplished. Look for such phenomena on the pot-hole bench near the large "wells." A much better place is at the intersection of Government and West streets opposite the residence of Mrs. R. C. Gray.

4.—Lithologic Varieties.

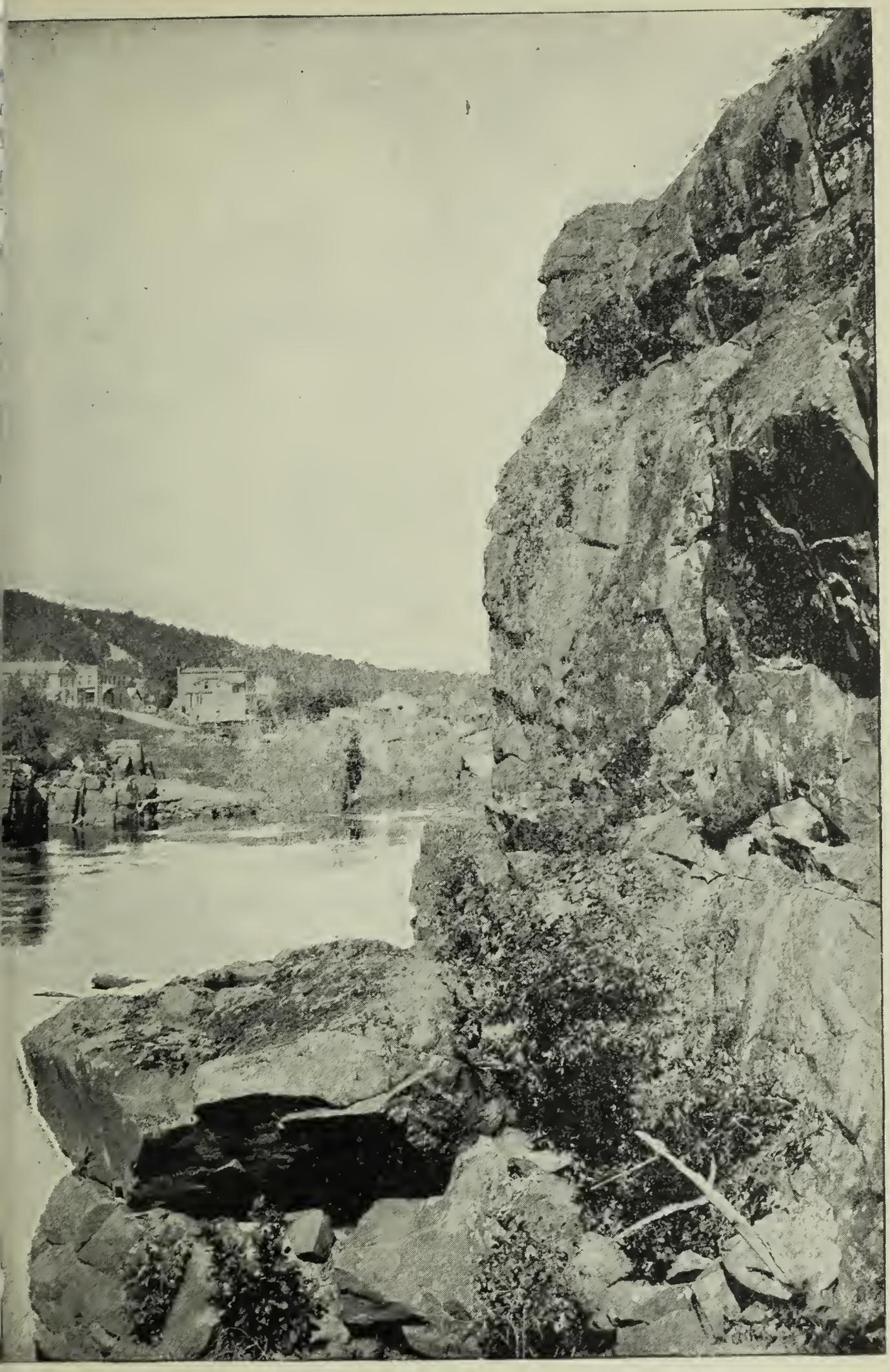
Besides the tuff just described, there are three or four typical phases of the crystalline rocks which should be recognized in this vicinity.

a. Lustre-mottled Diabase.—This is the spotted or mottled variety of rock which is so common in the lower flows. Its internal structure which produces this peculiar appearance consists of crystals of the mineral augite occurring in areas one-fourth to one-half inch in breadth in which are embedded numerous microscopic crystals of one of the feldspars. This is the so-called "ophitic" structure of petrographers. It is a noted character throughout the copper bearing rocks of the Lake Superior region.

b. Porphyry.—In the higher flows especially there is a considerable porphyritic development of the feldspar constituent. Many of these crystals are large, two or three inches long, and very abundant. In color they are much lighter than their matrix, usually flesh red or gray.

c. Amygdaloid.—This is a vesicular lava whose cavities have been filled with secondary minerals. It forms usually the surface of a flow, and the original cavities which characterize it are due to the expansion of steam or other gases imprisoned in the molten lava.

d. Pseudo-amygdaloid.—It is a rock in which cavities, resembling those of a true amygdaloid, have been produced by other processes since solidification and have subsequently been refilled with similar secondary products. This rock is rather common.



THE OLD MAN OF THE DALLES.

F—Decay of Rocks.

None of the rocks of this area are now in the original condition which they presented at the time of their formation. In many cases the rock as it now exists contains little of its original make-up, while in others of course there is not a great change. Water and air have destroyed and carried away many constituents and carried in and built up just as many others. Heat and pressure, two of the greatest agents in metamorphism, seem to have accomplished little here. But water has done wonders in these changes. It has dissolved the shells of animals that were buried in the sandstones and deposited the matter again around the grains of sand or on the river bluffs or in caves or crevices as a cement or as travertine or as crystallized calcite. It has dissolved iron compounds from the rocks and deposited them again in beautiful little concretions of iron pyrite in the lower shales. It has dissolved various elements from the igneous rocks and deposited them again as perfect minerals in the form of chlorite, epidote, quartz, etc., in the amygdules of the same rock. It has removed minerals from their places in the rock and at once replaced them, particle for particle, by some other minerals more suitable to existing surrounding conditions. It has dissolved a mineral from one place and carried it to another; it has destroyed one mineral to replace it by some other; it has carried away one substance to replace it by several; it has filled places where there was nothing before, and created cavities where there is nothing now—all so promiscuously that it might seem an accident, but all in very fact in accord with the most unyielding laws of nature. The change is, in general, from an unstable (easily decayed) rock to a comparatively stable one. So that some of these rocks, once a black, glassy basalt, composed of feldspar, pyroxene and magnetite, are now dark green crystalline rocks composed of quartz, epidote and chlorite. While the original rock was rather readily attacked by agents of decay, the green product now in its place is comparatively indestructible by such processes. But the changes are not complete. These rocks which seem so unchangeable are in reality changing from year to year, as they have always done in all the centuries that have already passed.

G—Minerals.

Although there are many different minerals present in the rocks in the vicinity of the Dalles, few of them are developed into good specimens of any particular species. Those which are represented by some characteristic association are given below:

Calcite—In clusters of nail-head and dog-tooth crystals filling cav-

ities and fissures in the conglomerates. Also often beautiful travertine along the river bluffs from Franconia southward.

Dolomite—Pearl spar crystals are rather abundant in the conglomerate outcrops near the Dalles.

Copper—Small amounts of native copper in the igneous rocks may be found in some places. Small quantities of other compounds of copper also occur.

Pyrite—In fine concretions about the size of a pin head may be found in the lower shales near the carding mill in Taylor's Falls.

Quartz—As sandstone it is very abundant. As an amygdule filling resembling agate is found rather sparingly, and crystallized in cavities, also, occasionally. As a secondary mineral scattered miscellaneously through the rocks it is very abundant.

Feldspar—An original constituent of the igneous rocks is abundant, especially in the porphyritic varieties. It is also developed as a secondary mineral with quartz and epidote in some cavities.

Epidote is the yellowish green mineral so abundant as a secondary product in the igneous rocks.

Chlorite is the dark bluish green secondary mineral accumulated most abundantly in amygdules and pseudo-amygdules.

Hematite—This oxide of iron is accumulated in some of the joints of the diabase in the railway cut near the Taylor's Falls station, and is abundant as a stain at many other places. It also produces abundant brown veins in the sandstone.

Other minerals in smaller amount or less conspicuous in obtainable specimens are augite, magnetite, kaolin, apatite, malachite, azurite, actinolite.

H—Life History.

One of the most interesting questions in the study of any period or the exploration of any area is the determination of the life record. This is usually preserved in a very broken way by fossil remains. It is incomplete because of the method of preservation of all these forms of life, and especially because many forms must have existed which could not be preserved at all. And broken because we can reach those which are preserved only here and there in a limited cut or quarry or river bluff where the rocks which buried them have been disturbed.

It is found in general that the higher forms of life have existed only in comparatively recent times; that the farther back in the geologic scale we go, the lower in the life scale the general aspect of the fauna descends; and that in the oldest rocks no traces of life are found at all, showing either that no forms of life existed or that those which did ex-

st were so simple and so fragile as to be utterly destroyed by the ordinary processes of fossilization.

So at the outset, if we wish to enter upon a study of the life record n the rocks of this locality, it will be well to glance once more at the :able of rock formations and geologic periods represented here. It will ɔe found that there are only three periods represented—the Glacial, the Cambrian and the Keweenawan. Of these the glacial period need receive no further attention because it is so recent that it represents essentially the present fauna and flora, except for the migrations which accompanied it. The rocks of the Keweenawan are eruptives in this locality and are therefore unfavorable for the preservation of fossils of any kind. It is, however, of interest to note that no well recognized fossils have yet been credited to the Keweenawan or to any earlier formation from the Keweenawan to the base of the geologic scale.

Of the Cambrian rocks, which are also represented at the Dalles, more should be said. Characteristic fossils of the Cambrian the world over are trilobites, which are crustaceans of a crab or crayfish-like structure or appearance, brachiopods, which are molluscoidea with a two-valve shell, and gasteropods, which are mollusca of a snail-like general appearance. All of them, however, are probably lower forms structurally than those to which I have likened them. All three of these types of fossils are represented in this district, and one of them at least, *Lingulepis acuminata* Con. (*Lingulepis pinniformis* Owen), is so abundant that no one need fail in obtaining good specimens. Another, *Obolella polita* Hall, is rather common. These are well known typical Cambrian brachiopods.

Trilobites are less common, but may usually be obtained in the conglomerates and associated sandstones. At Franconia, in the sandstone quarried there, large, good specimens may sometimes be obtained.

Fossils of the gasteropod type are rare and of great interest. They represent apparently the primitive forms of this group of animals in its early formative period. For example specimens may be secured which are perfectly straight like a cone, others that are curled over a little forward or backward, and still others which are fully coiled up like an ordinary snail. The gradation from one to the other is now so complete as represented by specimens in my private collection that there can be little doubt of their close relationship. It is not necessary to speculate as to how the primitive gasteropod on the seashore at Taylor's Falls came to know that a coiled shell or house would be of more use to him than a straight one; or indeed whether or not some change in local conditions may have coiled his shell for him in spite of his wishes.

On the whole the fossils found at the Dalles form a unique group in the paleontology of the Cambrian age.

PART III.

LOCAL GEOLOGICAL EXCURSIONS.

Several short local excursions have been planned for those who can spend but a short time at the Dalles and for those who are interested in particular features which they wish to examine. The object is to outline trips requiring from one to two hours to a full day's time in the field for each one, suggesting the order of points to be visited and noting the geologic or physiographic features worthy of attention. References are also made to pages in the text where more complete explanation is given. The hotels in Taylor's Falls are centrally situated for most of these short excursions and each trip is therefore begun and ended there. For travelers spending but one day at the Dalles, not more than two or three of these side trips can be made with moderate exertion. In order to see to advantage some of the most interesting phases of local geology much climbing is inevitable. To reach many points of importance long walks or drives are necessary.

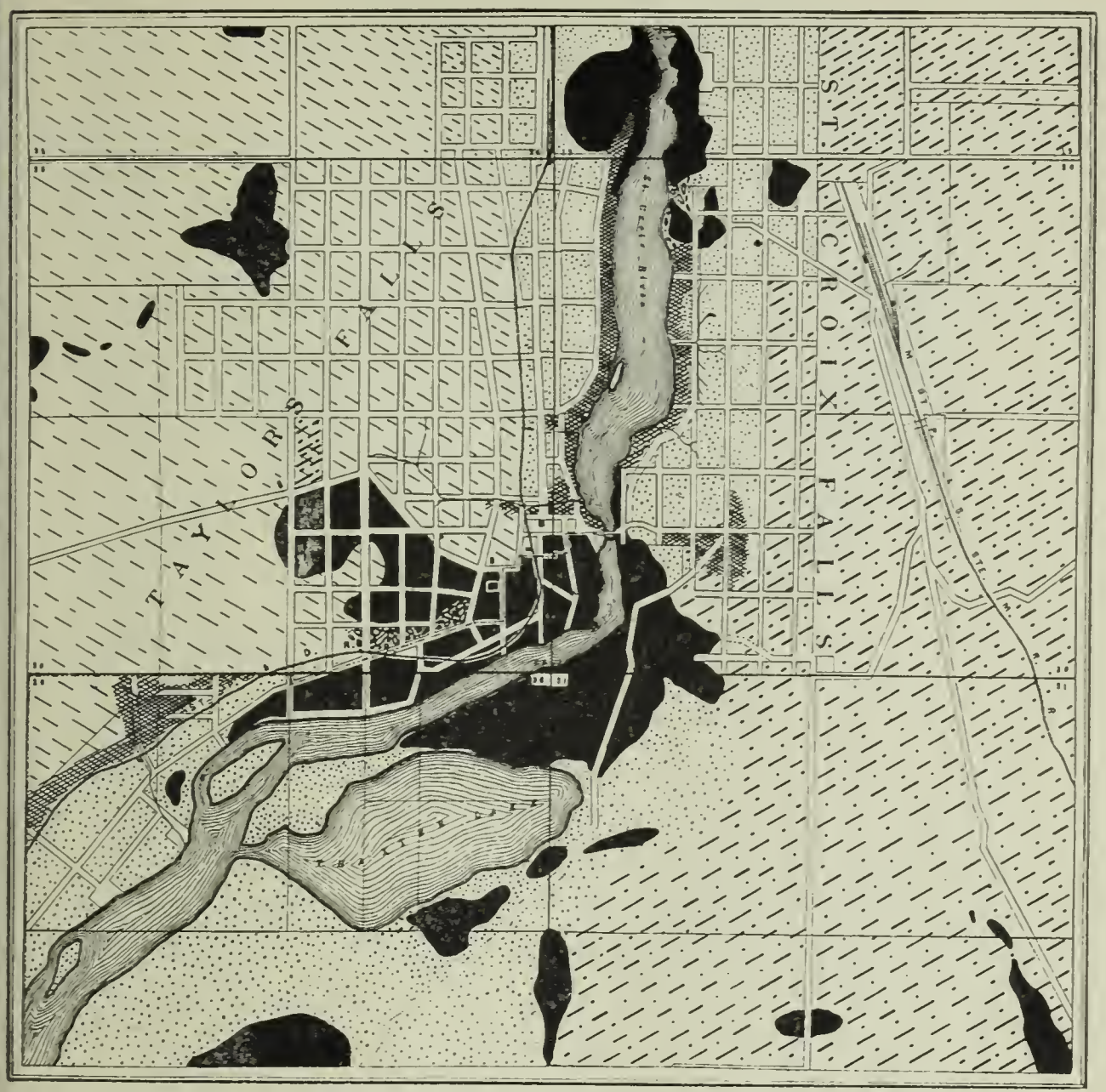
Wherever practicable the time usually required to reach points and return is indicated. Each separate trip is given a name suggested by the geologic feature of chief prominence to be seen.

SHORT EXCURSIONS.

I. In the Dalles. Pot-hole Erosion (one or two hours).
II. Keweenawan Lava Flows. Volcanic Ash and Breccia (tuff) (two or three hours).
III. Cambrian Conglomerates and Sandstones (two hours).
IV. The Glacial Drift. Eastern and Western till (one hour).
V. River History. Terraces (two hours).
VI. River History. Falls and Abandoned Channels (two or three hours).
VII. The St. Croix Moraine. Drift Accumulations (one-half day).
VIII. The Lower Gorge. A river trip to Osceola (one day).
IX. The Lower St. Croix. From the Dalles to Stillwater (one day).
X. Paleontology. Fossils and their Preservation (one day).

COMBINATION TRIPS FOR LARGE O NE-DAY EXCURSIONS.

XI. Combination No. 1. Including the chief features of II, III and IV above.
XII. Combination No. 2. Including the chief features of I, V and VI above.



KEWEE-NAWAN DIABASES. | CAMBRIAN CONGLOMERATES. | CAMBRIAN SANDSTONES AND SHALES. | STREETS. | EASTERN DRIFT. | WESTERN DRIFT. | ALLUVIUM.

GEOLOGICAL MAP OF THE INTER-STATE PARK AT THE DALLES OF THE ST. CROIX.

(An area two miles square drawn on a larger scale.
The Inter-State Park boundary on the west side of the river is indicated by a broken line.)

SHORT EXCURSIONS OUTLINED.

EXCURSION I.

In the Dalles. Pot-Hole Erosion. (Time one or two hours.) Pp. 12-13.

Plan. Start from the hotels. Go one block east, turn south and follow the street to the steamboat landing in the Dalles. The district to be studied lies between this street and the river. It may be explored thoroughly in the time indicated as it covers but three blocks at most. Follow the many foot paths through the pot-hole district.

Suggestions. Note the separation plane between two lava flows along the street within a block or less of the landing. Examine the perpendicular wall constituting the next flow. A lower flow may be seen later over at the river at the level of the toll bridge. Examine the numerous pot-holes. Large ones are situated in the lower portion of the district near the angle of the river. Note the different phases of the rock about them—amygdaloid and highly altered epidotic varieties. A bed of volcanic ash may be seen near the largest pot-holes and another of very limited extent near the toll bridge.

Examine the grinders taken from the holes; some very large ones may be seen. Note that in many places the dividing walls between two or more pot-holes have been worn away, forming large, irregular cavities. A narrow gorge entirely crossing the lower end of the district has been formed in this way by the destruction of the thin walls between rows of large pot-holes. Observe that the position of most of the pot-holes is such as to be subjected to great force from running water.

EXCURSION II.

The Keweenawan Lava Flows. Volcanic Ash and Breccia (tuff). (Time two or three hours.) Pp. 18-22.

Plan. Start at the toll bridge. Pass across the pot-hole district to the steamboat landing, thence up over the successive cliffs to the public school building and still farther west to the limits of the igneous rocks. Distance one-half mile. Rise 350 feet.

Observations. One flow at the toll bridge level is represented by a row of ledges, upon one of which the toll gate is built. Another is prominent at the street level 300 feet north of the steamboat landing, another 50 feet higher on the bench just below the railroad, another represented by the ledges through which the railway is cut, again one just below the public school building, and the most interesting one of all from the comparatively level tract or bench on which the schoolhouse is built.

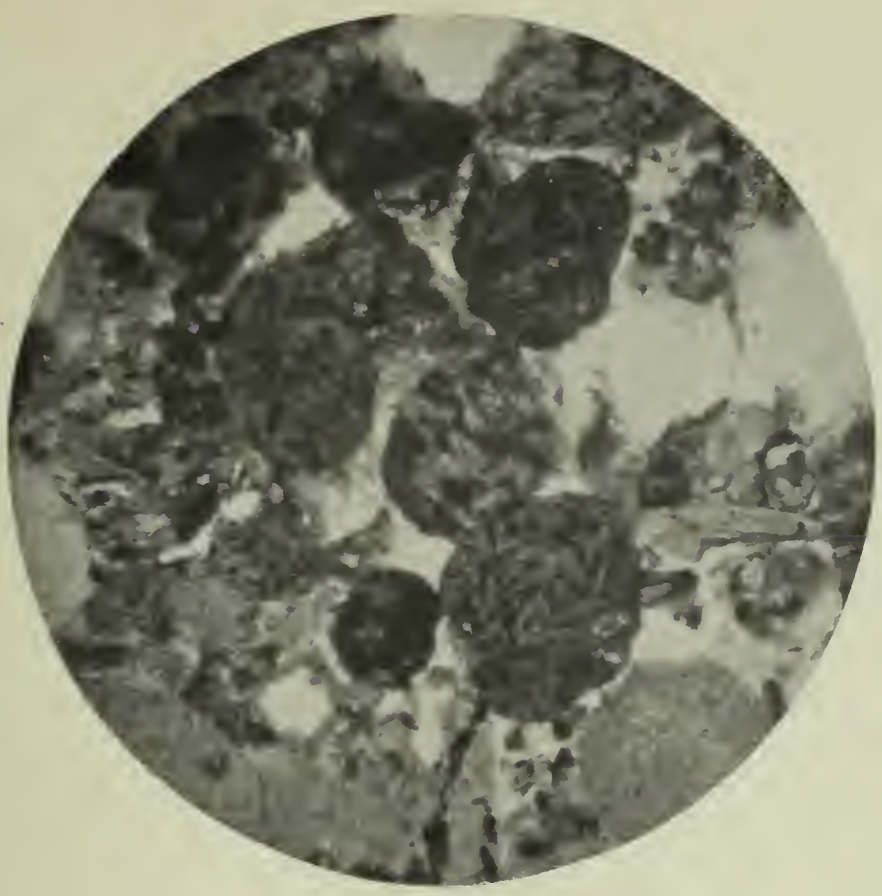


FIG. 3.—VOLCANIC TUFF.
(MAGNIFIED 40 DIAMETERS.)

("The figure is from a microphotograph of a section of the volcanic tuff from Taylor's Falls. Diabasic characters are shown by the darker grains in the figure and one fragment especially at the right side exhibits a coarser texture than is usual. Several grains near the lower margin of the field are devitrified glasses. In grains of this character flowage is sometimes prominent. The light colored fragments throughout the field are now chiefly quartz. But these almost all show their secon lary character by the penetration of actinolite needles which project in beautiful clusters. Finer fragments of a more angular outline lie between the larger grains.") Berkey,—*The American Geologist*, March, 1898.

Examine the volcanic ash and breccia (tuff) which is prominent one block farther west. Its thickness here is at least 20 feet between successive flows and represents either an interval of excessive disturbance and explosive activity or a much greater time break to allow the accumulation of so much debris. Splendid specimens of fine ash or water worn material or breccia may be obtained along this bed.

Other subdivisions of the formation may be recognized in a similar manner at higher horizons. Estimate dip and thickness. Note recurrence of structural and mineralogical characters—porphyritic, ophitic (lustre-mottled) and amygdaloidal phases, the accumulation of ash as separation planes, jointing, alteration and secondary products.

EXCURSION III.

Cambrian Conglomerates and Sandstones. (Time two hours.) Pp. 14-16.

Plan. Start at the schoolhouse. Go south on Mill street one block. Follow the street down the hill to the railroad, thence along the tracks to the first trestle bridge and return by way of the tracks to the depot.

Suggestions. Stop at the brow of the hill to see the magnificent outcrop of conglomerate in contact with the diabase. It has an iron oxide cement. Examine into the nature of the boulders of which it is composed. Get a good specimen. Note that occasionally a "tuff" boulder is included in the conglomerate among the others. What bearing has such observation upon the comparative ages of the two formations? Follow the outcrop down the hill and halt again near the railroad crossing. This is the celebrated Taylor's Falls outcrop of Cambrian conglomerate. Calcium and magnesium carbonates with sand serve as a matrix and cement here. Good small crystals of each may be found. Fossils are readily found. Rare types of trilobites and gasteropods are sometimes secured.

This is a famous locality among geologists as showing the "unconformity" of the Cambrian upon the Keweenawan series. Study the place so as to comprehend the situation which it represents at the time these conglomerates were formed.

Pass on along the railroad. Note the change rapidly to a finer grained and friable sandstone. Complex veining due to infiltrated iron oxide is seen in the sandstone. This is the *Franconia Sandstone* formation.

EXCURSION IV.

The Glacial Drift. Eastern and Western Till. (Time one hour.) Pp. 12-14.

Plan. Start from the hotels. The place to be examined is along the road which passes under the trestle and up the ravine bordering the "picnic ground."

Explanation. Red till partially stratified as if deposited in water lies at the base of the drift about 50 feet in thickness. It is the so-called "eastern drift." It is succeeded above by a thin bed of sand and gravel, which is known as "modified drift." Above still farther the blue or gray till, "western drift," completes the accumulation to the soil cap which forms the covering of the "picnic ground."

Note the characters of these three kinds of drift and the two kinds of till represented especially. They are as perfect examples of the kinds of drift covering Minnesota as can be found any place.

Red till is seen again higher up and several blocks farther west,

ear the Swedish church. It was deposited probably later than the gray ll of the "picnic ground," so that we have in all three separate sheets of ll represented at this locality. Most places on the opposite side of the ver only one can be made out.

XCURSION V.

iver History. Terraces and Erosion. (Time two or three hours.) P. 10.

Plan. Start from the hotels, Taylor's Falls. Cross the toll bridge. ollow the wagon road to the upper falls, where the igneous rocks oc- ur in the river again. Return by way of the principal business street of t. Croix Falls.

Observations. The hotels at the beginning are on a river terrace hich may be followed for a distance of a mile on the Minnesota side of ıe river. At places it is very level and has a width along River street f about two blocks. It is the fourth river terrace. It has a correspond- ıg development on the Wisconsin side of the river along the wagon oad where the springs are so abundant and where the flour mill is lo- ated. A lower terrace is represented by small areas near the toll bridge. he main business street of St. Croix Falls is built upon the second ter- ace. It can be followed throughout the village. The highest terrace long the St. Croix at this point is at 905 feet. It is observable on both ides of the river, but is especially prominent on the Minnesota side, here it forms the level tract known as the "picnic ground."

At the river level, at the upper falls, the formation of pot-holes is till going on. The most remarkable representatives of this peculiar rosion are apparently of very recent origin. A large rock barrier which ccupies the middle of the St. Croix gorge at this point is entirely cov- red with them.

In addition to these geologic features, collectors will obtain speci- ıens of fossils from the shales in the gorge; and botanists will be espe- ially interested in the plant inhabitants of the spring district on the ourth terrace.

EXCURSION VI.

iver History. Falls and Abandoned Channels. (Time two hours.) P. 11.

Plan. Start from the toll bridge on the east side of the river. Fol- ow the old road down past the elbow of the river along the abandoned iver channel to Thaxter lake. If plenty of time is left continue along ıe same road southward a mile or more through a rock-bound valley, hich constitutes a still older channel and which may be seen to best dvantage at about that distance.

Suggestions. It will be seen by this time that the great cliff forming the south wall of the Dalles must have been, at one time, an island in the St. Croix river. A portion of the river flowed through the gap where the road runs and plunged over the precipice which may be seen at a distance of four or five rods to the east. The great hole an eighth of a mile across, which lies at the foot of this fall, belongs to the accompanying erosion. The river at first flowed southwesterly through the earliest channel, abandoned at the 800-foot line; and later, when a lower outlet had been cut, it flowed westerly through the channel now occupied by Thaxter lake. Lake Thaxter is a good example of a river lake.

EXCURSION VII.

The St. Croix Moraine. Drift Accumulations. (Time one-half day.) P. 14

Plan. From St. Croix Falls follow the wagon road to the east one or two miles at least beyond the fair ground into the hill country. It may be studied at several other points equally well. If a full day can be spent, take the road to the north from the "Soo" depot toward Rock creek trout mere, or from the same place take the south road to Poplar lake. Either road passes through the moraine drift.

Observations. The characters of the drift show its "eastern" origin. The hilly portion forms a typical moraine. It may be easily crossed as it is only about one to two miles wide. This is a part of the celebrated "Kettle Range" and the so-called kettle holes are exhibited abundantly in the moraine. Many contain water, and small lakes are rather plentiful. They probably feed the numerous springs which issue at the higher levels. Note the almost entire lack of erosion here.

Small tracts dependent upon peculiar conditions surrounding the last glacial invasion and the retreat of the ice are seen here and there. For example, the level area at 1020 feet just east of St. Croix Falls, and the evidences of erosion along the road toward Dresser Junction, the deep valley of Rock creek and many others are of a good deal of interest if one succeeds in unraveling their history.

EXCURSION VIII.

The Lower Gorge. A River Trip to Osceola. (Time one day.)

Plan. Take a row boat to Osceola and return. Stop at Franconia at conglomerate cliff, at travertine cave, at Osceola falls, at Eagle point and at the quarries in Osceola. The lower Dalles are near Franconia.

Suggestions. The gorge can be studied to very good advantage. Note whether there is any evidence of its pre-glacial existence. At Franconia see the Lawrence creek gorge and get some fossils. This i

EAGLE POINT NEAR OSCEOLA.

SHOWING ONEOTA DOLOMITE CAPPING THE JORDAN SANDSTONE.

ıe type exposure of the *Franconia sandstone*. At Conglomerate cliff ote that there is no accompanying diabase ridge. At the cave just bove this place get specimens of compact banded travertine. At Eagle oint see the *Oneota dolomite*. The *St. Lawrence shales* are exposed in ıe creek gorge below Osceola falls. Another abandoned channel may e seen at the railway station. Good fossils may be secured from the *ordan sandstone* in the old quarries just north of the village. Note that his is the northern limit of the *Oneota dolomite*.

EXCURSION IX.

The Lower St. Croix. From the Dalles to Stillwater. (Time one day.)

Plan. Take the steamboat from Taylor's Falls to Stillwater.

Suggestions. Note the succession of formations which follow eacl other in the river bluffs,—The *Keweenawan* volcanic rocks, the *Dresbac* shales, the *Jordan* sandstone, the *Oneota* Dolomite.

A part of the lower gorge is pre-glacial. Determine its beginning

EXCURSION X.

A Hunt for Fossils. (Time one day.)

Plan. Visit the shales in the river gorge at St. Croix Falls, th conglomerate outcrop at Taylor's Falls, the Lawrence creek gorg at Franconia and the abandoned sandstone quarries at Osceola.

Observations. The shales at St. Croix Falls carry the best speci mens of the well-known *Lingulepis acuminata* Con. (*Lingulepis pinnifor mis* Owen). The conglomerates at Taylor's Falls contain rare types o gasteropods. Among them are *Hypseloconus recurvus* Whitfield an *Tryblidium rectilaterale* Berkey, besides many related species describe by these two men. Rarely a completely coiled form belonging to *Scae vogyra* or *Euomphalus* may be found. Trilobites are more common Several species of *Agraulus* are reported from this place. The rares species are *Ptychoparia calymenoides* Whitfield and *Cheilocephalus st croixensis* Berkey. Only two of the former and one of the latter hav been reported. Besides these, good specimens of *Obolella polita* Hall, small brachiopod, are abundant.

At Franconia trilobites are almost the only fossils obtainable. Bu some of them are splendid specimens. *Dicellocephalus misa* Hall is th largest and most common species.

At Osceola the best specimens are of species of *Dicellocephalus* and few gasteropods, among which *Pleurotomaria* (*Holopea*) *sweeti* Whitfiel is the best known.

COMBINATION TRIPS FOR LARGE ONE-DAY EXCURSIONS.

COMBINATION NO. 1.—10:30 A. M. to 1:00 P. M.

Itinerary. The train will usually stop on such occasions a mile ou of town for the accommodation of the excursion. Start at one of th sandstone cliffs. From that point follow the railroad in to the stree crossing, thence by the street over the hill to the schoolhouse, thence b way of the depot to the ravine at the base of the picnic ground.

hings to see and places to look for them:

1. The *Franconia sandstone* along the railway.
2. *Cambrian* conglomerate along Mill street below the schoolouse.
3. Volcanic *Keweenawan* rocks at the schoolhouse.
4. Volcanic breccia and ash (tuff) one block west of the schoolouse.
5. Eastern and Western till at the base of the "picnic ground."
6. The highest terrace, the "picnic ground" itself.

Lunch—1:00 P. M. to 2:00 P. M. At picnic ground, or the hotels, r in the Dalles.

COMBINATION NO. II. 2:00 P. M. to 6:00 P. M.

Itinerary. Follow the street from the hotels to the steamboat landng in the Dalles. Pass through the pot-hole district to the toll bridge. ross the river and follow the road to St. Croix Falls. Reach the river gain at the upper falls. Return by way of the main business street of t. Croix Falls or along the river within the most recent gorge.

hings to see and places to look for them:

1. Great pot-hole, a few rods northeast of the boat landing.
2. Separation between two lava flows, along the street leading to oat landing.
3. The Dalles, pictured rocks, from the elbow of the river.
4. Large grinders, in one of the great "wells" near the center of he pot-hole district.
5. "The old man of the Dalles," from the toll bridge.
6. The fourth river terrace, along the road at the flour mill.
7. Good spring water, and plenty of it, on the fourth river terrace.
8. The second river terrace, along the main business street of St. Croix Falls.
9. Fossils—*Lingulepis acuminata* Conrad, in the river gorge above he mill.
10. The lower *Dresbach shales*, in the river gorge.
11. Pot-holes in process of formation, at the upper falls.
12. Calcite crystals (dog-tooth and nail-head spar), in the river gorge.

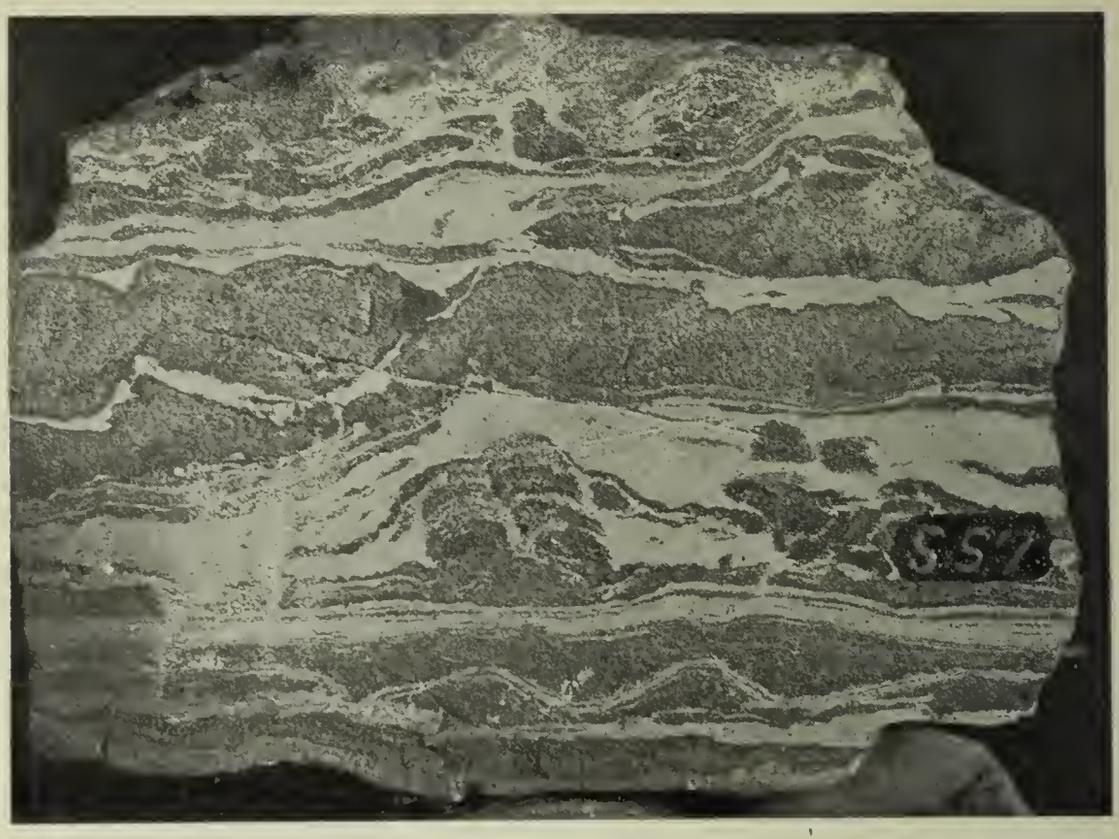


Fig. 4. ST.LAWRENCE SHALES.

(REDUCED ONE-THIRD.)

The figure is reproduced from a photograph of a hand specimen collected at Osceola Falls. The darker portions represent quartz sand; the lighter wavy bands are greenish dolomitic clay shale. To satisfactorily explain the origin of such a rock is a problem of considerable complexity.

EXPLANATION TO PLATE I.

Fig. 1. *Lingulepis pinniformis* Owen.
Lingulepis acuminata Con. (Walcott.)
Fig. 2. *Hypseloconus* (*Metoptoma*) *recurvus* (Whitf.), var. *elongatus* Berkey.
Fig. 3. *Agraulus convexus* Whitf.
Fig. 4. *Ptychoparia calymenoides* (Whitf.), (and head of *A. convexus.*)
Fig. 5. *Agraulus convexus* Whitf., (senile individual.)
Fig. 6. *Hypseloconus stabilis* Berkey.
Fig. 7. *Agraulus convexus* Whitf., (average size.)
Fig. 8. *Hypseloconus recurvus* (Whitf.), (small.)
Fig. 9. *Euomphalus strongi* (Whitf.), var. *sinistrorsus* Berkey.
Fig. 10. *Hypseloconus franconiensis* Berkey.
Figs. 11-14. *Hypseloconus recurvus* (Whitf.), (three different forms.)
Fig. 15. Fragment of a partially coiled form of undetermined affinities.
Fig. 16. *Hypseloconus recurvus* (Whitf.)
Fig. 17. *Tryblidium rectilaterale* Berkey.
Fig. 18. *Tryblidium convexum* Berkey.
Fig. 19. *Cheilocephalus st. croixensis* Berkey.
Fig. 20. Slabs showing several casts of *Hypseloconus recurvus.*
Fig. 21. *Hypseloconus recurvus* (Whitf.), var. *elongatus* Berkey.

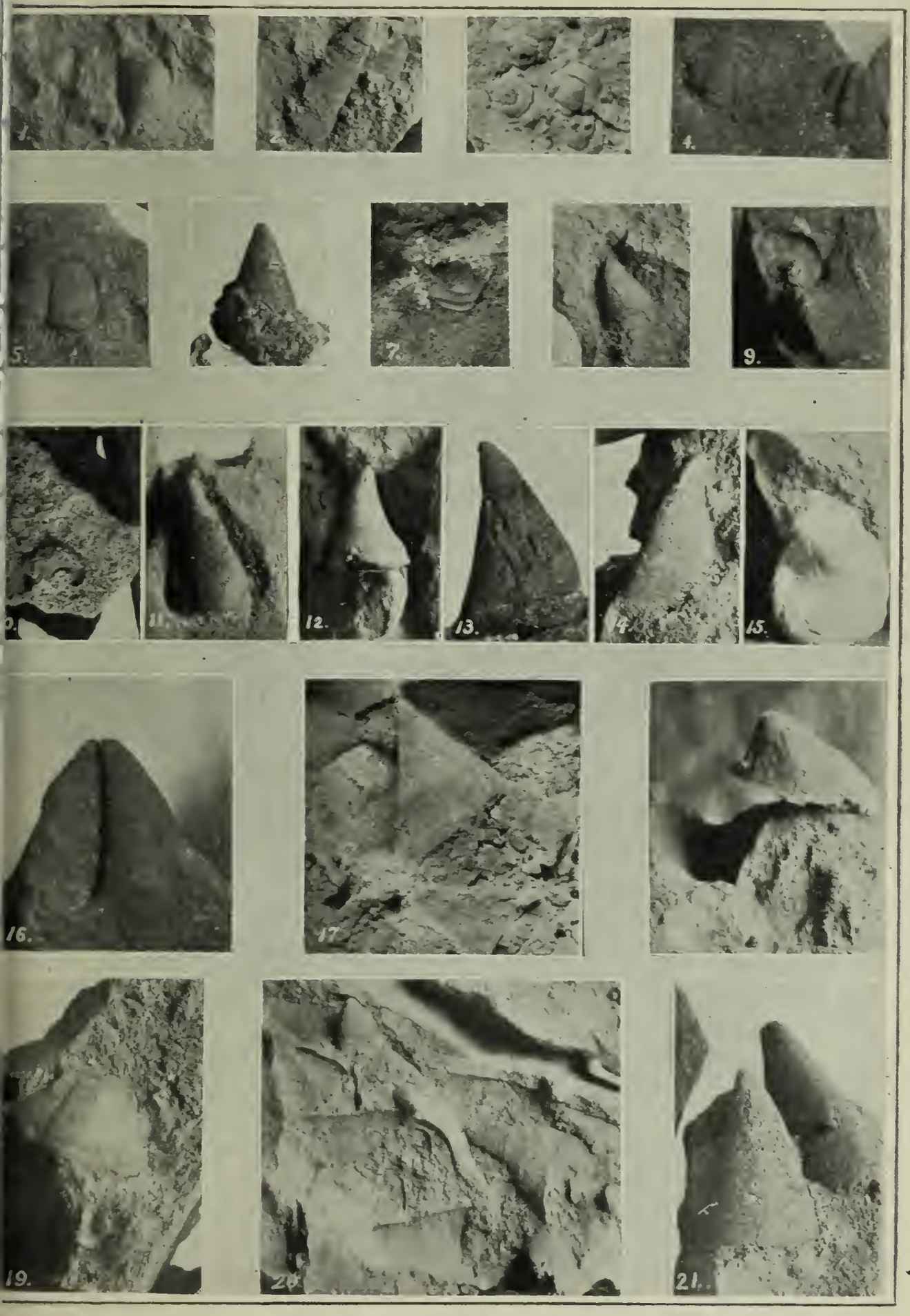


PLATE I—CAMBRIAN FOSSILS.

ACKNOWLEDGMENTS.

I am indebted to the St. Paul & Duluth R. R. for several of the cuts used by me in this pamphlet. Several others have been reprinted by permission of *The American Geologist* in whose pages the writer has recently used them in illustration of his thesis on the "Geology of The St. Croix Dalles." And I take this opportunity of acknowledging my obligations to Mr. C. E. Stone of the St. P. & D. R. R., and Mr. Geo. H. Hazzard, Commissioner of the Inter-State Park, for many helpful suggestions in the prosecution of my task.

CHARLES P. BERKEY.

Minneapolis, June 23, 1898.

PARLOR, HOTEL COCHECO.

A. E. FREDEEN, PROPRIETOR, TAYLOR'S FALLS, MINN.

OUTLINE MAP SHOWING THE LOCATION OF THE DALLES.

RUSSELL COFFEE HOUSE CO.,

14-16 South Fourth St., Minneapolis, Minn.

Meals Served from 6:30 a. m. to 8:00 p. m.

STRICTLY FIRST CLASS. PRICES REASONABLE.

THE HOTEL—EUROPEAN—50 ROOMS,

Conducted in connection with the Russell Coffee House, occupies the three floors above and has Elevator, Steam Heat, Electric Bells Lights and all Modern Conveniences.

RATES:—50C, 75C AND $1.00 PER DAY